[illegible] for most of the twenty years following the

2. The NPRM Proposals

a. The Commission's proposal to separate narrowband and wideband pulse-ranging systems is in the public interest

Teletrac's Petition proposed that the Commission continue the separation contained in the explicit language of the 1974 interim rules -- i.e., that narrowband and wideband pulse-ranging systems be separated from one another. Appendix 2 to the Petition, a study of the impact of co-channel interference on wideband pulse-ranging systems, concluded as follows

> Even a moderately powered interfering source located inside the service area reduces coverage substantially. A high powered interfering source, transmitting at the edge of the service area similarly damages coverage.
>
> -- Petition, Appendix 2, at 30.

Opponents of this incontrovertible truth claimed that this effect resulted from faulty system design rather than physics (see NPRM ¶¶ 12-13), but offered no technical analysis to support this assertion. The Commission has accordingly proposed that all narrowband systems be licensed in 902-904, 912-918 and 926-928 MHz. NPRM ¶ 15. Teletrac supports that proposal, and it is fully supported by the evidence of record.[21]

We believe that the amount of spectrum being proposed for narrowband systems (902-904, 912-918 and 926-928 MHz) is likely to be sufficient to accommodate foreseeable needs. NPRM ¶ 17.

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[21] We also support the Commission's proposal to include wideband non-pulsed systems in this allocation. Proposed § 90.209(10).

numbers of narrowband systems in the wideband pulse-ranging allocation, would turn the current chill on wideband pulse-ranging licensees' incentives to construct into a deep freeze. One need only read the recent filings by the Association of American Railroads and the Interagency Group to realize the deluge has already started.[23] This result is illogical at best. It will result in a high transition cost with little public benefit -- e.g. large numbers of narrowbands to be moved, so few or no new widebands will be built until the migration is complete. On the other hand, the cost of immediately shifting new narrowband receivers to non-interfering frequencies is quite low.

Teletrac's Petition proposed to grandfather all narrowband licenses as of the date of the Petition, May 26, 1992, since that would, we assume, impose less costs on existing licensees than a forced migration. That proposal was made in the Spring of 1992 before the deluge began. Now that it is apparent that a large

licensing in the bands proposed for narrowband operations, 902-904, 912-918, 926-928 MHz. There is no basis for continuing to protect licensees who entered the band after the date of the Petition, since the cost of shifting is low while the cost to

that suggests a 4 MHz system is even economically viable. Pinpoint, for example, has applied for 8 MHz, but has maintained it needs much more for its system to be efficient.[26] It is quite likely that without the opportunity to provide a wide array of applications to diverse sets of consumers, the costs of wideband pulse-ranging LMS will be prohibitive, precluding profitable, low cost, mass marketing.[27] The wideband system which can cover large metropolitan areas would be rendered useless. Accordingly, Teletrac is unable to suggest a method whereby wideband pulse-ranging and narrowband systems can co-exist.

b. Wideband sharing is not feasible

The NPRM proposal that wideband pulse-ranging systems share spectrum is subject to the caution "assuming that sharing of this spectrum is feasible." NPRM ¶ 22. It is not. It is inconsistent for the Commission to separate wideband pulse-ranging systems and narrowband systems into different frequency bands based on interference considerations, while not separating one wideband pulse-ranging system from another. A wideband pulse-ranging interfering signal raises the same interference

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[26] Opposition of Pinpoint Communications Inc. at 6, filed in this docket July 23, 1992.

[27] Jansen Decl. at ¶ 6. Several commenters have pointed out that Teletrac has quite explicitly stated that at present it uses 906-910 MHz. However, the system is designed to use and achieves its cost efficiencies only by using 8 MHz. As demand grows and new services are added, economic viability depends on the ability to use 8 MHz. See Schmalansee-Taylor Study at 32-34.

concerns as an ensemble of narrowband systems spread across a wideband channel.

The NPRM accepts the consensus view that narrowband systems will interfere with wideband pulse-ranging systems. NPRM ¶ 12. It may be possible to engineer a wideband system to filter out narrowband signals when (a) the frequencies of those signals are known in advance; (b) the affected frequencies are few; and (c) the number of interfering sources is limited. Where narrowband signals are random in number and location throughout the band, this filtering would not be practical. Even where narrowband signals are established according to fixed patterns across the entire wideband, filtering would not be "reasonable or cost-effective." Id. at ¶ 14. For this reason, the NPRM proposes that narrowband systems no longer be licensed on wideband channels, id., and existing narrowband licensees would move to other frequencies. Id. at ¶ 16.

But the NPRM fails to take the next step and recognize that an ensemble of narrowband interference sources looks like a wideband interferer. This is particularly true where, as here, the wideband systems employ spread spectrum techniques. The despreading function of the receiver transforms narrowband signals into wideband noise.

Based on this logic, two wideband pulse-ranging systems operating on the same channel in the same city are likely to

interfere with one another.[28] Consequently, the proposal to license multiple wideband pulse-ranging systems on a channel NPRM ¶ 21) is inconsistent with the finding that narrowband and wideband systems cannot coexist.

(i)
The IVHS America Reply Comments on which the Commission relies do not support its proposal

One rationale advanced for the proposal is that "exclusive use of 8 MHz assignments will lead to a higher cost to the public both in terms of use of the spectrum and in terms of cost for subscribing to an LMS service (because of decreased competition)." NPRM ¶ 21. The NPRM's cited source for this statement is a three page Reply Comment filed by the Intelligent Vehicle Highway Society of America (IVHS America), dated August 7, 1992. In these three pages, only five paragraphs deal with the Teletrac petition. Even that brief discussion is primarily directed to the issue of maintaining narrowband identification systems in the wideband pulse-ranging allocation. See IVHS America Reply Comment ¶ 1. IVHS America's comments offers no support, analytic or otherwise, for the broad statements challenging co-channel separation which are contained in the NPRM.[29]

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[28] The Teletrac Study, Appendix 2 to these Comments, shows explicitly that this occurs in the real world.

[29] Teletrac became a member of IVHS America after these IVHS America Reply Comments were filed.

The IVHS America Reply Comments contain significant errors. For example, the Reply Comments suggest that, historically, wideband systems were allocated 8 MHz because they could co-exist with narrowband systems. Id. ¶ 4. However, there is nothing which supports this contention. Wideband channels were authorized because pulse-ranging AVM technology required wideband channels in order to deal with multipath. Mitre Corporation, author of the IVHS America Reply Comments, should know its statement is erroneous. After all, Mitre said in 1973

> . . . Pulse ranging techniques have an inherent advantage in multipath environments, because reflected signals normally arrive after the direct path signal has triggered the receiver and produced a time-of-arrival measurement. . . . The price paid for this advantage is the large bandwidth that is required for the transmission of short pulses with fast rise-times. UHF pulse ranging techniques typically require a bandwidth of about 10 MHz.[30]

In short, the IVHS America Reply Comments are no support at all for anything, certainly not for the otherwise unsupported allegations concerning competitive benefits for which they are cited in the NPRM.

(ii)
Technical studies show that sharing between wideband pulse-ranging systems is not feasible

The Commission states in its discussion of narrowband systems that co-channel noise makes it difficult for a wideband system to operate, NPRM ¶ 14, but limits that analysis to

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[30] Overview of Automatic Vehicle Monitoring Systems, Mitre Corporation, MTP 386, August 1973, at 13.

narrowband-wideband systems. Strangely, the Commission seems to ignore the noise problem in its inquiry into whether wideband pulse-ranging systems can co-exist with one another. Yet, Pinpoint, a principal proponent of wideband sharing has already effectively conceded that sharing is unlikely to work in any practical sense.[31]

Teletrac commissioned Professor Pickholtz to analyze the impact of sharing between wideband systems.[32] The Pickholtz Study concludes that "sharing among LMS systems is not reasonably feasible for a variety of reasons." Pickholtz Study at 1. Harmful interference can adversely affect wideband pulse-ranging systems by causing:

[redacted]

As the Pickholtz Study explains, location systems differ from communication systems in several fundamental ways. Pickholtz Study at 14. For example, a location system must use multiple fixed points to process a single pulse while communications systems can use a single receive point. Id. In communication systems, direct sequence spread spectrum protects against noise and multipath, while in location systems, direct sequence techniques provide for a high pulse power and high bandwidth without requiring high peak power. Id. Professor Pickholtz concludes:

> Unless one takes into account the different objectives of these two quite different types of systems, it is easy to mislead oneself in the analysis of these systems. One must be careful not to apply concepts from data communications uncritically to analogous issues in the analysis of pulse-ranging LMS systems.
>
> -- Pickholtz Study at 14.

The Cramer-Rao bound, a statistical measurement, provides an excellent tool for examining the tradeoffs [redacted]

Teletrac system operates at or near the Cramer-Rao bound. Id. at 20-24.

The design tradeoffs the Cramer-Rao bound assesses in an LMS system are:

-- mobile unit costs;

-- operating costs;

-- accuracy sufficient to meet consumer demand; and

-- system availability.

Id. at 20. Unless these tradeoffs are made correctly, a viable system cannot be created or maintained.

To demonstrate the impact of co-channel noise, Teletrac engineers used an analytic model, based upon radio propagation modeling and the fundamental performance limits of hyperbolic navigation systems. (Teletrac Study at 3).

> The Teletrac experiments and analysis show that an LMS system that can function acceptably well in the 902-928 MHz band sharing environment will fail in the presence of interference from a co-channel LMS base station.
>
> -- Pickholtz Study at 26.

The Teletrac model was used to predict how a system like the one proposed by Pinpoint would operate in the presence of wideband interference. (Teletrac Study at 2, 7). The study concludes that performance of a Pinpoint-like system will be significantly impaired by wideband interference Id. The model was validated by experiments using the Teletrac system in Dallas-Fort Worth. Id.

Since co-channel operations will cause harmful interference under any reasonable use of that term, Professor Pickholtz examined whether there were any solutions to the problem.

First, time division multiple access (TDMA) was examined (Pickholtz Study at 27-34), but that approach creates insurmountable technical and economic hurdles.

> Time-division sharing of LMS bands appears ill-advised. When the FCC chose to license two cellular providers in each market using frequency division techniques, it recognized that this policy choice created competition at the expense of a 10-15 percent increase in network infrastructure costs. In contrast, time-division sharing of LMS bands would increase costs by more than 100% when adding a second firm in a band. Time-division sharing would limit important technical alternatives. Any of the firms sharing a band could costlessly expand capacity to fill the band, creating incentives against technical innovation and for cheating.
>
> -- Id. at 33-34. (Emphasis supplied).

Second, frequency division was examined. However, the Cramer-Rao bound demonstrates that operating a pulse-ranging LMS system in half the bandwidth reduces capacity by a factor of four. Id. at 34. That would make wideband technology infeasible. As Mr. Jansen states, a wideband system such as Teletrac must be able to provide personal location services to individuals to be viable. Jansen Decl. ¶ 3. That requires small low power transceiver units and substantial additional system capacity. That will not be possible in 4 MHz.

However, this would create the tragedy of the commons scenario as other firms in the band responded by increasing the power of their transmitters. Id. at 35-36; Petition at 25-26.[34]

Fourth, interference can be overcome, or at least coped with, by measuring the pulse over a longer time. Of course, this is expensive and difficult since the system architecture must be changed. Pickholtz Study at 36. Moreover, increasing measurement time decreases capacity quite significantly, e.g., a fifty percent reduction in capacity can only reduce interference offsets by 3 dB. This "fix" also causes the tragedy of the commons to occur because longer duration pulses increase the amount of interfering energy which other systems must deal with. Id. at 37. Finally, there is no assurance this approach would work. Id.

Fifth, the bandwidth could be increased if it were available. Doubling the bandwidth cancels out a fourfold increase in noise power. Id. at 37. However, to cancel interference under a relatively "benign" scenario where the co-channel base station is ten miles away would require the bandwidth to be increased by a factor of fifty -- i.e., from 8 to 400 MHz. And, if the base station were closer than 10 miles, the bandwidth increase would be greater. Id. at 38.

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[34] There are also practical limits. As power levels increase, a system becomes more expensive and current FCC regulations limit pulse-ranging systems to a maximum of 1,000 watts, while the NPRM proposes a limit of 300 watts. See proposed § 90.205.

As Professor Pickholtz explains,

> Another way to look at this result is to observe that two cochannel systems operating in 400 MHz and generating sufficient interference with one another to raise the noise floor by 34 dB will have the same capacity as two systems operating in 16 MHz and using frequency division multiplexing to divide the spectrum. This may explain why the FCC's 1974 order set up a regulatory environment with two subbands.
>
> -- Id. at 38.

Sixth, the interfering signal can be suppressed. Unfortunately, existing suppression solutions are not technologically practical. Id. at 39.

Seventh, more receive sites may alleviate interference. Id. at 42. But again, if anything but the most favorable assumptions are used, the gain may be nonexistent. Id. Moreover, this is a very expensive and inefficient solution. Doubling the receive sites may double the cost of the fixed network. Id. And obtaining useful sites may be difficult or impossible. Id. In any event, this solution does not solve the problem created by a single high power interference source located in the middle of an LMS service area. Id.

Finally, geographic and co-channel separation can be used and is the surest method of preventing unwanted interference. Id. at 43. According to the Pickholtz Study:

> The biggest benefit of the approach when compared to all others is that it leaves LMS system operators with the least uncertainty regarding potential interference from other LMS systems.
>
> -- Id.

In short, co-channel separation is practical, technically correct and supported by a wide array of technical evidence.

(iii)
Sound economic analysis suggests there is no policy basis for wideband pulse-ranging systems to share spectrum

The arguments advanced in favor of spectrum sharing for wideband systems have a largely economic flavor. As set forth in the NPRM, proponents of spectrum sharing contend it would allow additional competitors into the market for LMS services, thus "promot[ing] competition within the LMS industry and continued technological advances in LMS services, possibly leading to more robust systems and more efficient spectrum sharing." NPRM ¶ 21. Proponents also argue that allowing "exclusive use of 8 MHz-wide assignments will lead to a higher cost to the public both in terms of use of the spectrum and in terms of cost of subscribing to an LMS service (because of decreased competition)." Id.

No evidence or economic analysis in support of these contentions is set forth anywhere in the NPRM. Indeed, as discussed above, the only authority cited are reply comments which do not even address the issue. In fact, the NPRM's proposal to license multiple AVM systems in each of the 904-912 and 918-926 MHz bands is not supported by fact or economic theory. Rather, it is a threat to sacrifice present real benefits to consumers on the basis of speculative claims of future benefits.

(a)
Spectrum sharing will impose large and unwarranted costs on the LMS industry and LMS users

LMS services, like many other consumer services, require a low unit cost and a low monthly cost. Without such competitive pricing, the benefits of this service cannot be offered to large numbers of consumers, and LMS providers will not be able to recover the high fixed costs of LMS service. Jansen Decl. at 2. Spectrum sharing will, in numerous ways, work against that goal.

Assuming arguendo that sharing is feasible, it would impose substantial additional costs on LMS service providers. LMS providers would be forced to undertake strategies to deal with that interference, including significantly reducing the capacity of their systems, increasing the number of receive sites by 100-fold to 1000-fold, or changing mobile units to transmit at levels of power so high that the units would cost thousands of dollars. Each of these responses to increased interference will substantially increase the unit costs of providing LMS services. Under such a scenario, it is unlikely that these services will remain viable. See id.; Schmalensee-Taylor Study at 36-37.

Yet the cost burdens of spectrum sharing do not end with the interference problem. Assuming, contrary to past history, that multiple AVM providers enter the market, each would be required to duplicate a number of facilities in order to serve the market. These include equipment and facilities, marketing and advertising, and so forth. Schmalensee-Taylor Study at 28. LMS systems are highly complex; the necessary facilities include a

control center with sophisticated computing equipment, numerous receive sites with the technology necessary to measure the time of arrival of signals to approximately a billionth of a second

this spectrum, and would further exacerbate the unit cost problem discussed above.

First, each LMS system in the market is required to use some spectrum for so-called "overhead transmissions" -- i.e., transmissions necessary to calibrate and synchronize the system. For example, if overhead requirements for a single system are 10% of total system capacity, increasing the number of systems in an area from one to four causes the ratio of overhead transmissions for the entire spectrum to jump from 10% of total system capacity to 40%. See id. at 30 and Table 1. In the real world the loss would be worse, because each firm would incur additional overhead implementing a mechanism to operate in the shared environment.

This effect exacerbates the diseconomies of scale already

The unit cost of each firm operating on 4 MHz in a divided bandwidth environment would thus be at least quadruple that of a firm operating over 8 MHz. Each system would obtain only half the capacity for its expenditure, thus doubling its unit costs, and would have to spread those costs over half the number of subscribers, thus doubling them again. See Schmalansee-Taylor Study at 33. Again, this analysis does not even include the additional overhead costs of system sharing (assuming such synchronization were even possible). The benefits of additional entry would have to be large indeed to justify such waste.

(b)
The uncertainty resulting from spectrum sharing would impose additional costs

"Open entry" increases the risk associated with developing an LMS system. New entrants will not be sure what the effective capacity of their system will be in the shared spectrum environment; the greater the number of additional entrants the smaller each entrant's capacity. Moreover, "open entry" is really limited entry. The band cannot hold an infinite number of competitors. Thus, at some point quickly reached an additional entrant will create total chaos. Potential co-channel interference completes the picture of uncertainty, since it makes investors and customers uncertain as to whether and under what circumstances this system will work. The resulting disincentive to invest will harm the development of LMS systems.

(c)
There are no significant competitive benefits from sharing among wideband pulse-ranging systems

Sharing proponents seem to argue that if only one wideband pulse-ranging system is licensed in each 8 MHz band in an area, a "duopoly" of LMS services will result. Since each wideband pulse-ranging system will face many competitors other than the other wideband pulse-ranging system in the market, this statement is devoid of any economic significance.[36]

Moreover, there are strong policy reasons for believing that a sharing regime would actually be anticompetitive. For example, expanding the number of competitors will not lead to more technological diversity. As the Schmalensee-Taylor Study explains

> Co-channel separation does not reduce technological diversity. Under the Teletrac proposal, only two WBPR LMS systems can compete in the 900 MHz bands in a single geographic market, but both systems would have a incentive to innovate or to adopt any technologies that lowered costs or expanded capacity.
>
> Id. at 20-21.

Moreover,

> [w]hatever advantage multiple providers would have in theory in supplying diversity would be offset in practice by the conforming requirements imposed by the need to share and

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[36] Wideband LMS services already compete with numerous other providers of similar services. LoJack, and Trimble and other GPS systems offer LMS services. Emerging traffic service companies, and even broadcast radio, offer substitutes for the commuter services LMS providers would offer. Cellular providers offer a substitute for consumer applications such as roadside assistance. Schmalensee-Taylor Study at 10.

> coordinate use of the spectrum. Moreover, some LMS servicers, e.g., personal location services, require more bandwidth than others, so that restriction of the bandwidth available to a WBPR LMS provider less than the full 8 MHz may actually reduce the availability of services.[37]
>
> Id. at 23.

LMS providers will compete with numerous other providers of wireless information services, in one of the most fluid and competitive areas of the economy. See Jansen Decl. ¶ 3. New technologies could bring new companies into the market at any time. To argue that any company could enjoy a comfortable "duopoly" in such an environment is to ignore reality.

New entry itself does not provide competitive benefits. Rather, the new entrants must provide lower prices to consumers, or new service options, to provide a true benefit.

Here, however, new entry would raise unit costs in the industry quite substantially, making it quite unlikely that lower prices would be the result. See Schmalensee-Taylor Study at 13-14. In addition, even without additional entry, LMS providers could not raise prices significantly above competitive levels since demand for LMS services is elastic. See id. at 11. Attempts to raise prices would simply drive consumers away. Moreover, the sharing regime required if multiple wideband pulse-ranging systems are located on the same frequencies in the same

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[37] There will also be substantial competition among equipment vendors regardless of the number of licensees in a market. Teletrac, for example, does not manufacture its own equipment and numerous firms are competing to supply innovations to the system.

geographic area would likely undercut any possible competitive gains from additional providers. Id. at 11-12.

Finally, the Commission could achieve any perceived economic benefits without sharing by permitting and encouraging resale by the two wideband pulse-ranging providers. See id. at 41-42.

The pseudo-economic suppositions advanced in the NPRM to support the desirability of spectrum sharing have no support in fact or theory. The economic fact is that wideband sharing of the type proposed in the NPRM will impose enormous costs to obtain speculative "benefits" which do not appear significant in any case. Such a sharing proposal should be rejected.

(iv)
The Commission has used co-channel separation to achieve public benefits

The Commission has often recognized the benefits of co-channel separation in increasing channel capacity, promoting the efficient use of spectrum, simplifying the administrative burdens on the Commission and its licensees, and thereby improving the quality of the services provided. In several cases, the Commission's action has come after unsuccessful experience under a spectrum sharing regime demonstrated the infeasibility of sharing.

The Commission has recently stated:

> the concept of exclusivity has gained such

The Commission has very recently proposed to provide channel exclusivity for qualified private paging systems.[39] Nonexclusive frequencies in the 900 band have proved unworkable and undesirable, with a disproportionate impact on wide-area systems.

> Wide-area systems typically transmit simultaneously to all points, and some of the larger systems are moving to initial distribution of signals by satellite. If the frequency is shared, however, the entire system may be required to operate on a part-time basis in order to accommodate a paging system that serves a much smaller area. The potentially disproportionate effect of non-exclusivity on wide-area systems is an obvious disincentive to investment in such systems.[40]

Separation, on the other hand, offers substantial benefits.

> Paging operators on a common frequency must [redacted]

MHz.[42] Without significant regulatory changes in those bands, "the quality of PLMR communications will likely deteriorate to the point of endangering public safety and the national economy."[43]

> Spectrum crowding causes serious problems for private land mobile users. Safety related communications, for example, require clear, usable channels. Reliable mobile communications also improve industrial productivity.[44]

The Commission noted that channel exclusivity promotes competitive benefits.

> Channel exclusivity provides incentives for users to operate in the most efficient mode available. Users also have the flexibility to install highly efficient technologies . . . .[45]

In fact,

> The exclusivity created by this plan would also promote long term spectrum efficiency because users with exclusivity should consider spectrum efficiency as an important factor in seeking to maximize the value of "their" spectrum. In addition, technical flexibility would allow a licensee to determine whether to implement another spectrum efficient technique or technology.[46]

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[42] Replacement of Part 90 by Part 88 to Revise the Private Land Mobile Radio Services and Modify the Policies Governing Them, 7 FCC Rcd 8105 (1992).

[43] Id. at 8105.

[44] Refarming Notice of Inquiry, 6 FCC Rcd at 4126.

[45] Id. at 4127.

[46] Id. at 4134.